Murder Most Foul, Strange, and Unnatural
The London Polonium-210 Incident: A Paradigm for Radiological Event Public Health Investigations?

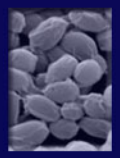
CAPT Jeffrey B. Nemhauser, MD

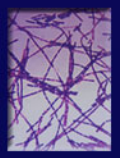
♦

Radiation Studies Branch
Division of Environmental Hazards & Health Effects
National Center for Environmental Health
Centers for Disease Control & Prevention
Atlanta, Georgia







Ghost: Revenge his foul and most unnatural murder.

Hamlet: Murder!

Ghost: Murder most foul, as in the best it is,

But this most foul, strange, and unnatural.

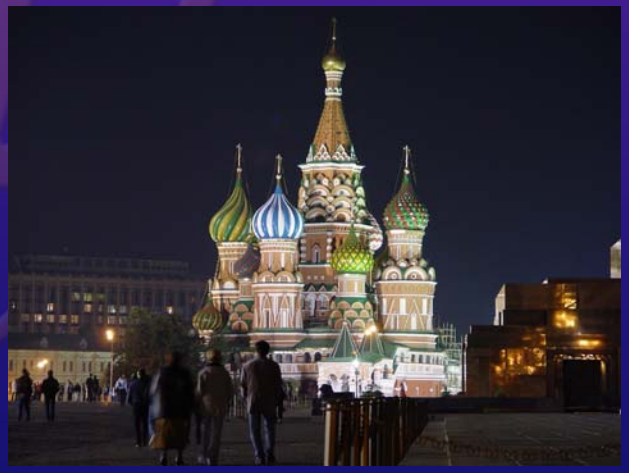
The Tragedy of Hamlet Prince of Denmark (Act I, Scene V)

The views and opinions expressed by CAPT Nemhauser are not necessarily those of the Centers for Disease Control and Prevention.

Political Poisonings in History

- Emperor Claudius of Rome, 54 – mushrooms?
- King John of England, 1199 – ale? plums?
- Giovanni Borgia, 1497 – ???
- Sir Thomas Overbury, 1613 – copper vitriol
- Grigori Rasputin, 1916 – cyanide
- Felix-Roland Moumie, 1960 – thallium
- Georgi Markov, 1978 – ricin
- Khaled Marshal, 1997 – ???
- Viktor Yuschenko, 2004 – dioxin

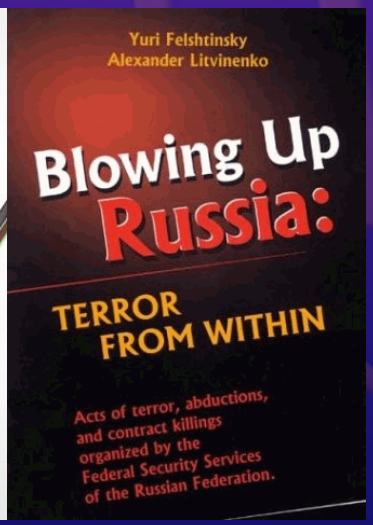
Alexander Litvinenko



- Former Russian military officer
- 1988: Joined KGB counter-intelligence
- 1991: Worked for Russian federal security service (FSB), fighting terrorism and organized crime
- 1997: Began investigating "organized criminal formations“
- 1998: Arrested and imprisoned on charges of exceeding his authority at work – claimed FSB had ordered him to kill Boris Berezovsky

Alexander Litvinenko

- 2000: Secretly left Russia, ended up in London and re-united with Berezovsky
- 2001: U.K. granted him political asylum
- Before his death was investigating murder of Russian investigative reporter Anna Politkovskaya
- Both Litvinenko & Politkovskaya: outspoken critics of Putin government

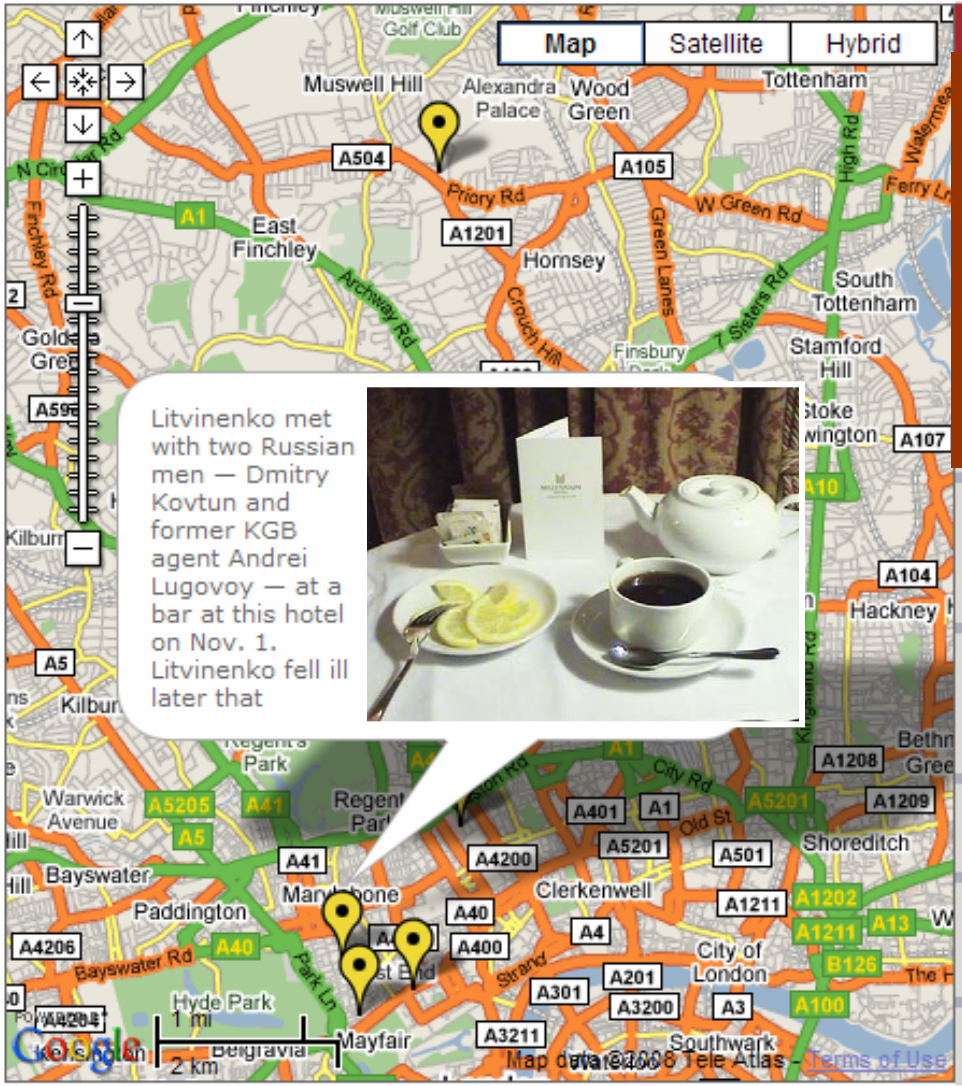


INTERACTIVE MAP

Alexander Litvinenko

London radiation locations

More on famous poisonings »



TIMELINE

Nov. 1, 2006
Former Russian spy Alexander Litvinenko meets two Russian men, Andrei Lugovoi and Dmitry Kovtun, at the Pine Bar in the **Millennium Hotel** for tea. He also meets Italian academic Mario Scaramella at a **sushi restaurant**. Later that evening, Litvinenko falls ill.

Nov. 4
Litvinenko is admitted to **Barnet General Hospital** with stomach pains.

Nov. 17
Litvinenko is transferred to the **University College Hospital.**

Nov. 20
Litvinenko is moved to intensive care.

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Nov. 24
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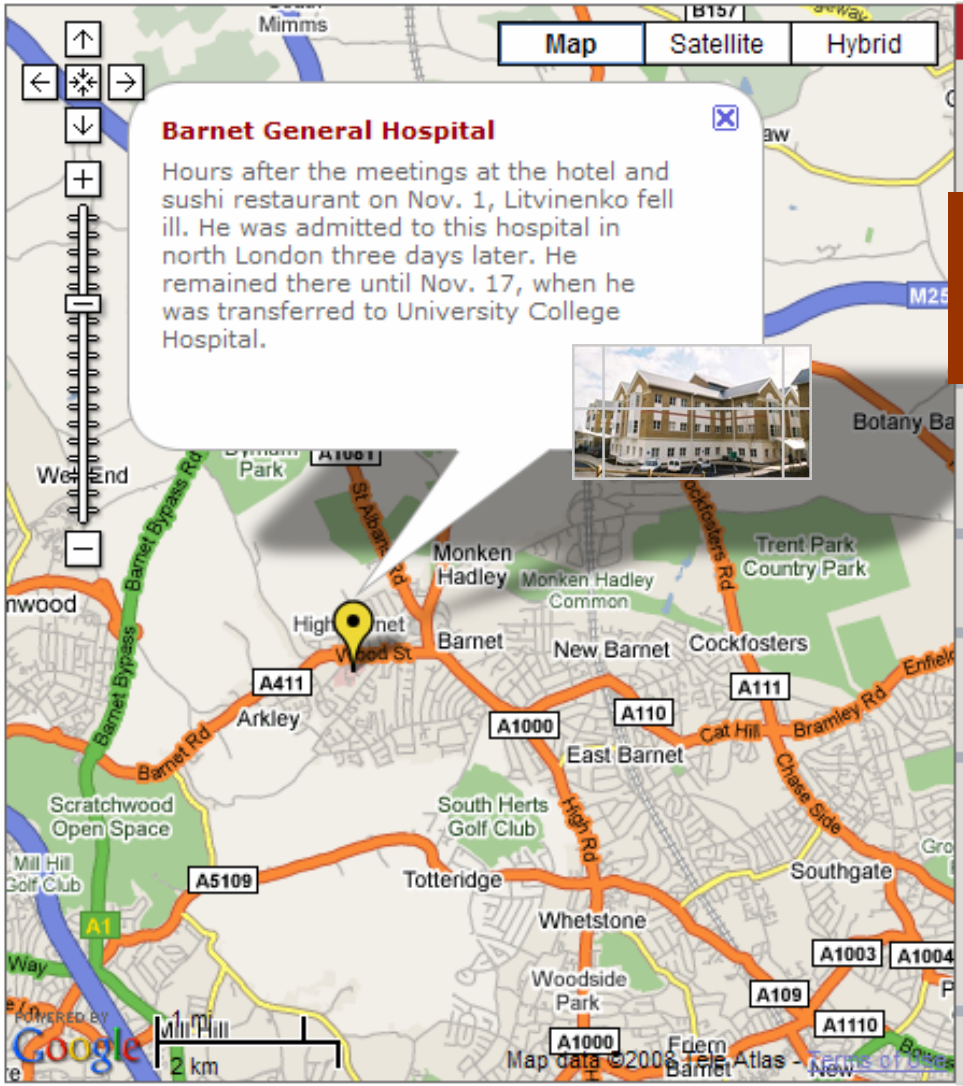

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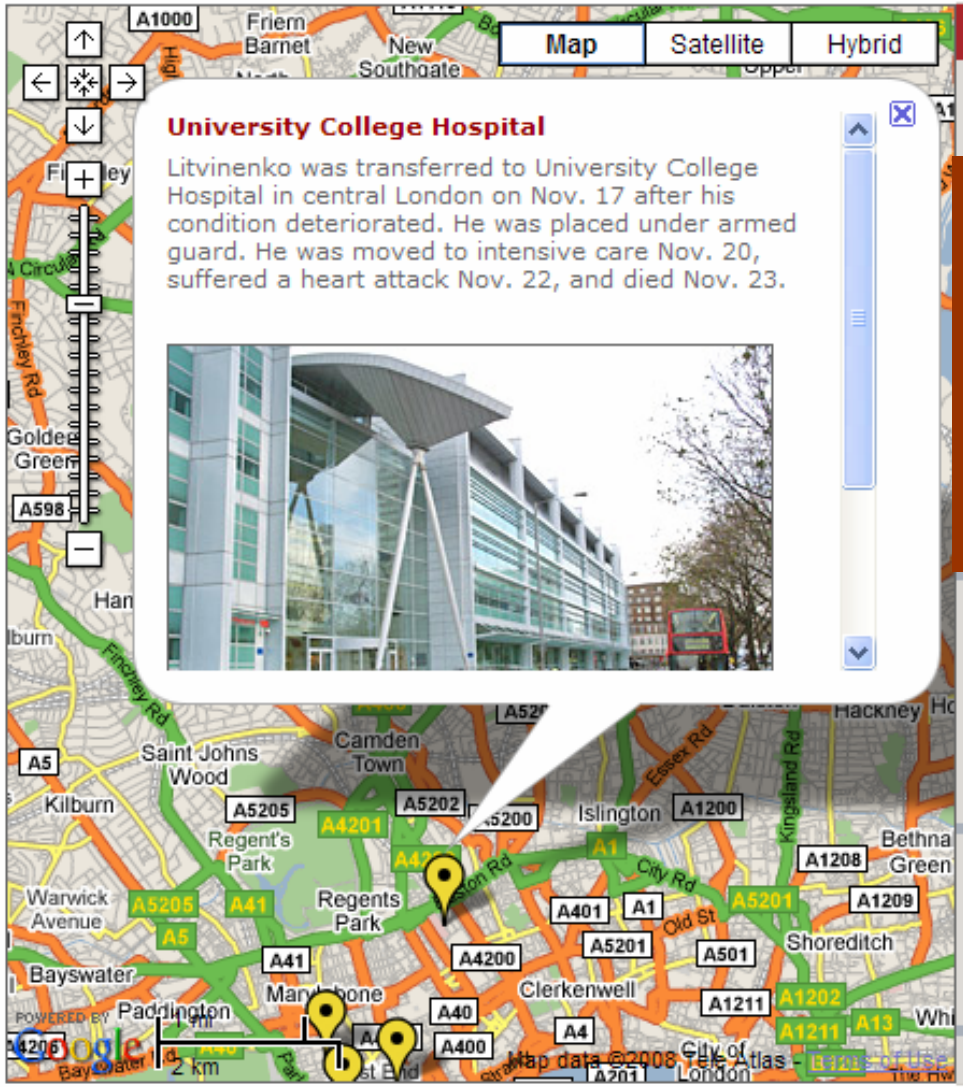

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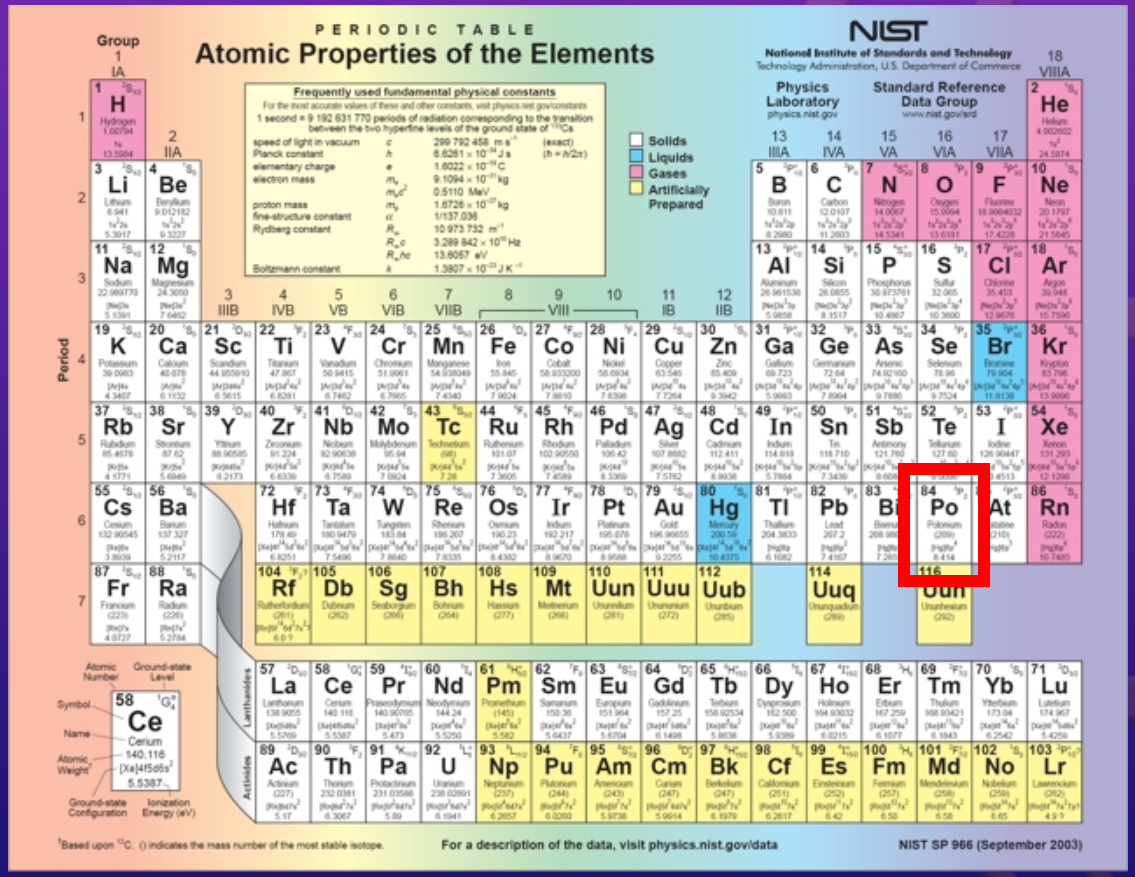
Nov. 29
Traces of a radioactive

Cause of Death

- 23 November 2006
  - Litvinenko died from Acute Radiation Syndrome due to Po-210 intoxication
- Acute Radiation Syndrome
  - aka Radiation Sickness
  - Occurs as a result of high-dose, ionizing radiation, delivered over a short period of time, and involving most or all of the body
  - Primarily affects hematopoietic, gastrointestinal, and neurovascular systems

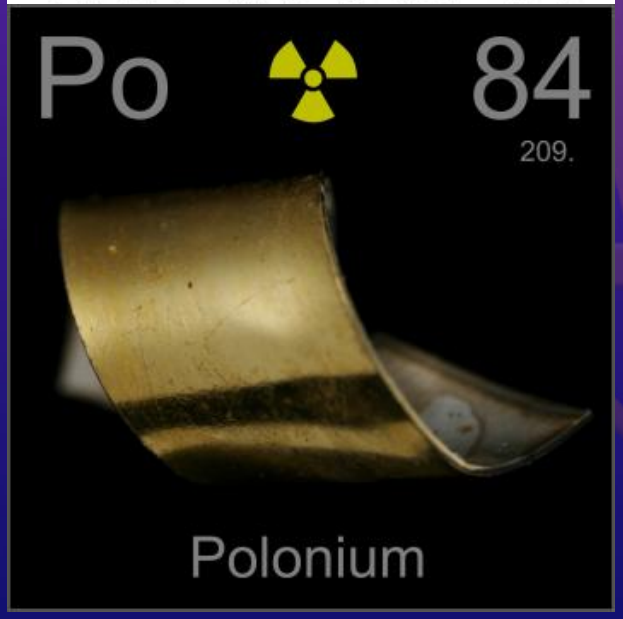
Polonium-210 (Po-210)

- 1898: Discovered by Marie & Pierre Curie
- First element on the periodic table for which all isotopes are radioactive
- Normally solid metal at room temperature



Polonium-210 (Po-210)

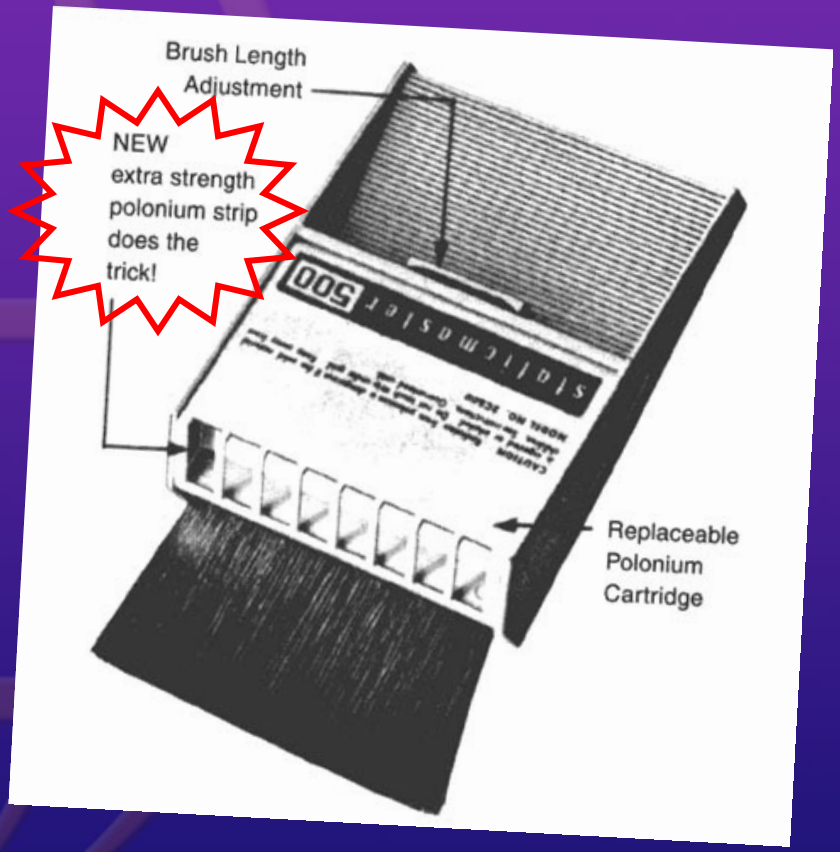
- Dissolves readily in dilute acids
- Easily airborne in natural state
- Sticks to glass
- Has tendency to “creep” and contaminate environment



Naturally-occurring Po-210

- Found in high concentrations in tobacco leaves, lichen
- Concentrates in skeletal muscles of grazing animals

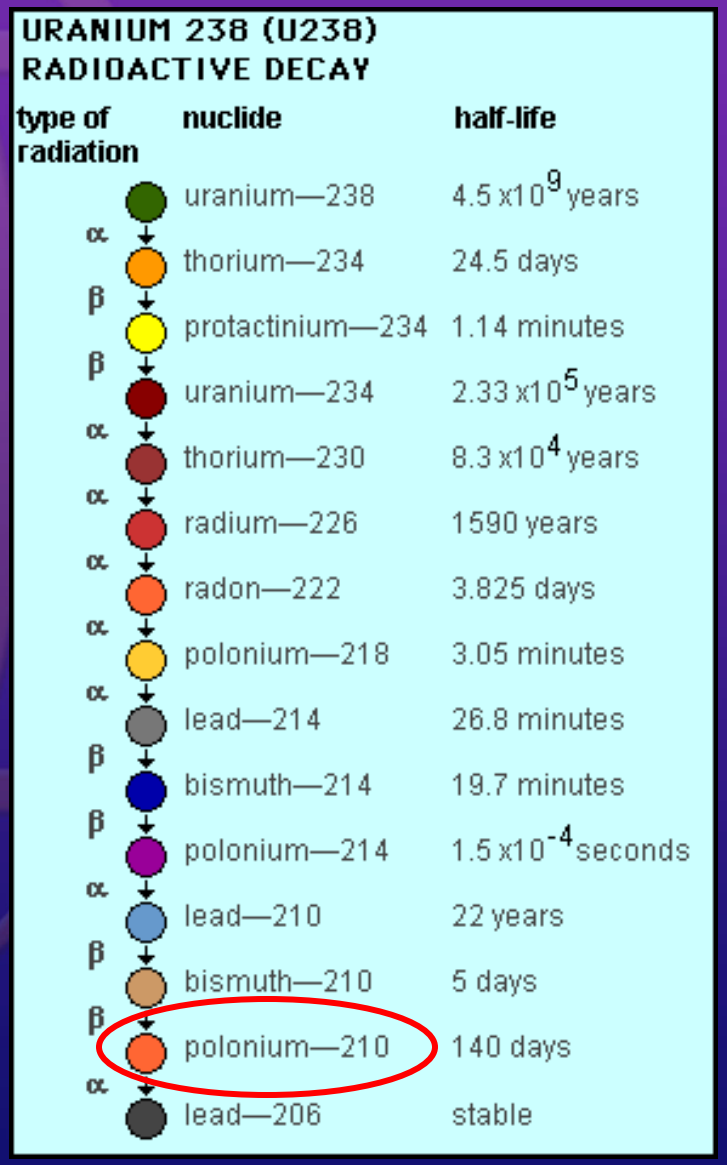
Man-made Po-210



"StaticMaster" Static Electricity Eliminator
Rolyn Optics Co., Covina CA

- Produced in nuclear reactors
- Formerly used in nuclear weapons and power generators for space program
- Now used to eliminate static electricity

Po-210 Decay



- Physical half-life: 138.38 d
- Biological half-life: 50 d
  - Excreted in urine, feces, sweat
- Effective half-life: 36.7 d
- Decays by alpha (α) particle decay 99.999% of the time

Po-210 Decay Scheme

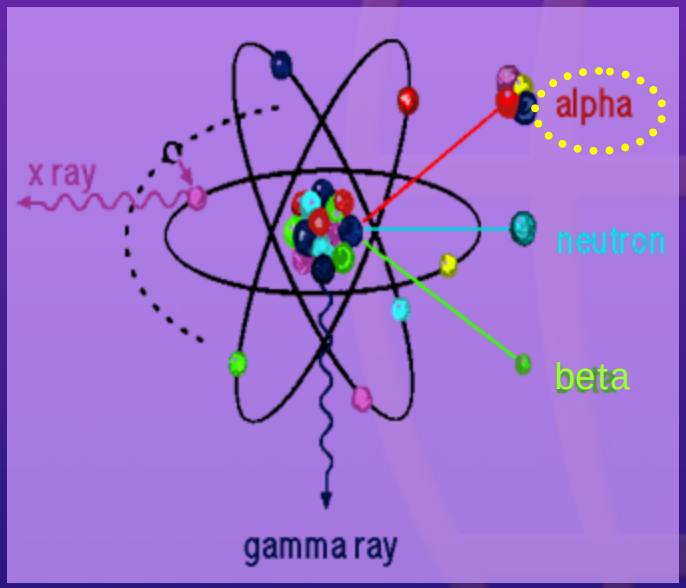
$$^{210}_{84}\mathrm{Po} \rightarrow {}^{206}_{82}\mathrm{Pb} + \begin{cases} {}^{4}_{2}\alpha\ (5.3045\ \mathrm{MeV}) \quad 99.999\% \\ {}^{4}_{2}\alpha\ (4.524\ \mathrm{MeV}) + \gamma\ (0.8031\ \mathrm{MeV}) \quad 0.001\% \end{cases}$$

Geiger-Mueller (GM) Counter with β-γ probe

Geiger-Mueller (GM) Counter with α probe

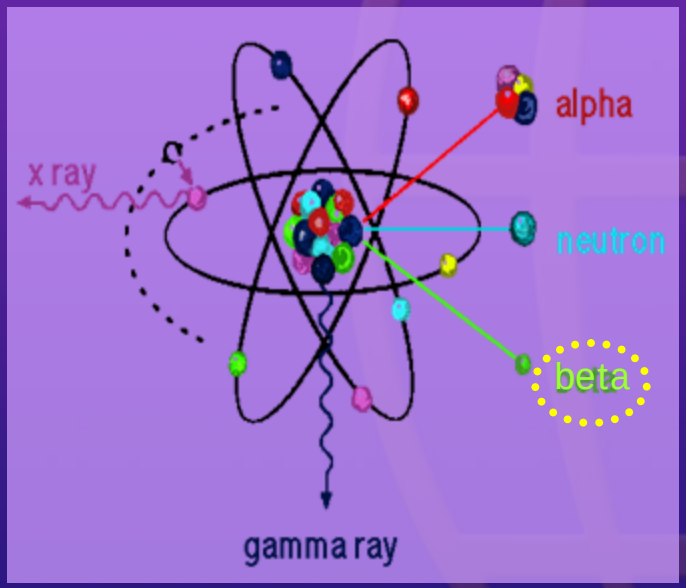
Types of Ionizing Radiation

- Alpha (α) particles
  - Two neutrons and two protons
  - Least penetrating
    - Travel 1—2 cm in air and only microns in tissue
    - Cannot penetrate skin



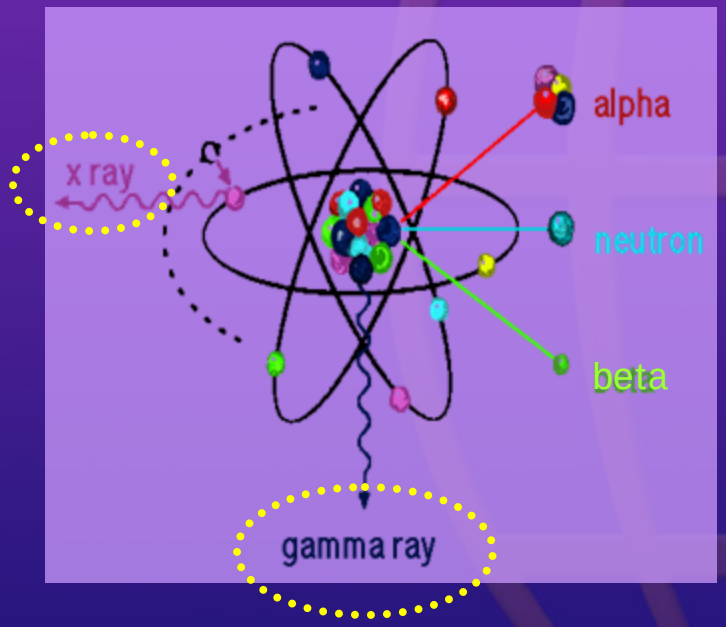
Types of Ionizing Radiation

- Beta (β) particles
  - Free electrons
  - More penetrating than α
    - Travel several meters in air
    - Can penetrate and burn skin, damage eyes
  - Stopped by aluminum foil or heavy clothing



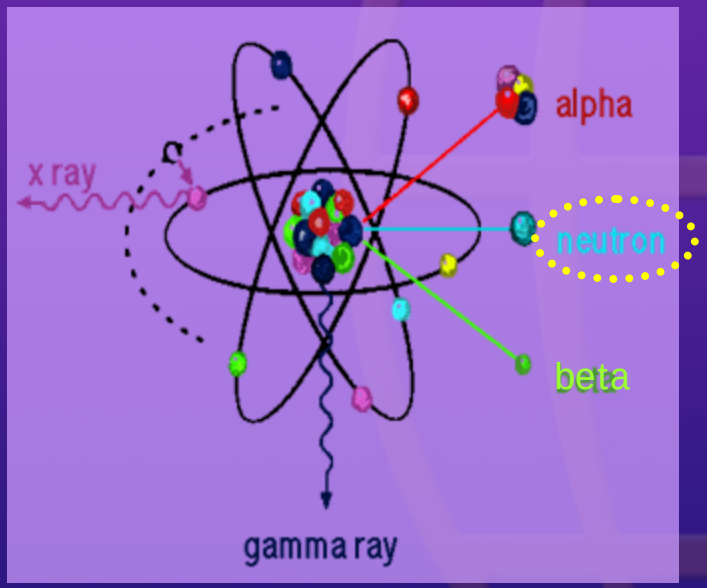
Types of Ionizing Radiation

- Gamma (γ) rays and X-rays
  - Very high energy radiation
  - Penetrate tissue deeply
  - Primary cause of acute radiation syndrome
  - Requires thick lead shielding for protection

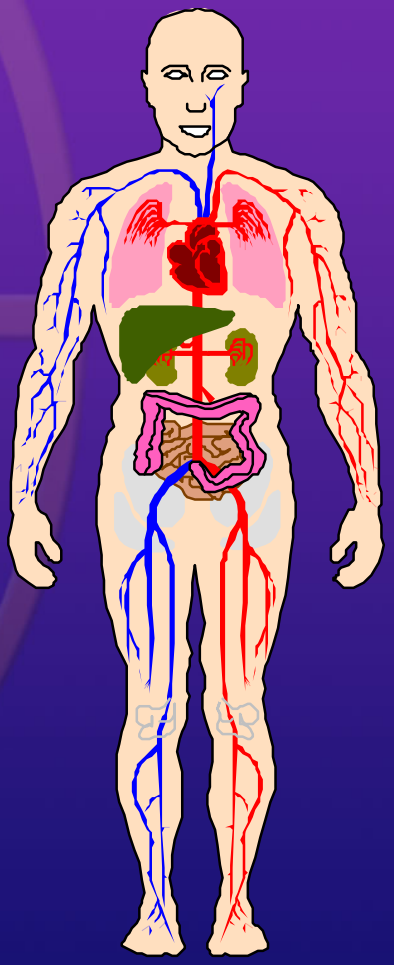


Types of Ionizing Radiation

- Neutrons
  - Very penetrating
    - Can damage tissue on contact
  - Produced by detonation of atomic bomb
  - Can make previously stable materials radioactive
  - Thick concrete barrier for shielding



Po-210 as Radiation Hazard



- External hazard? Not!
  - α-particles travel short distances in air and are easily stopped
  - Po-210 γ-ray emissions: 0.001%
- Significant internal hazard
  - Distributes throughout body
  - High Linear Energy Transfer of α-radiation is what makes this element so hazardous

News

- National Press Releases
- NRPB Archive
- PHLS Archive
- Press Enquiries

Mr Alexander Litvinenko- Health Protection Agency Statement

Printer friendly page (opens new window)

24 November 2006

The Health Protection Agency can confirm that it is providing expert advice as part of the Metropolitan Police investigations into the death of Alexander Litvinenko.

Tests have established that Mr Litvinenko had a significant quantity of the radioactive isotope Polonium-210 (Po-210) in his body. It is not yet clear how this entered his body. Police are investigating this.

Po-210 occurs naturally and is present in the environment and in people at very low concentrations. As it emits alpha particles, Po-210 can represent a radiation hazard if it is taken into the body - by breathing it in, by eating it, or if it gets into a wound. It is not a radiological hazard as long as it remains outside the body.

The Agency is providing radiological protection advice to staff at the two hospitals which treated Mr Litvinenko and specialist monitoring teams will also d etermine whether any radioactive polonium-210 contamination has spread in the hospital areas he was cared for. Other specialist monitoring teams will examine other locations, including Mr Litvinenko's home.

Agency staff will be contacting heath care workers involved in the direct care of Mr Litvinenko, as well as those who may have had very close contact with him when he was ill - including his family. This will involve a simple questionnaire and the provision of a urine sample if appropriate.

Professor Pat Troop , Chief Executive of the Health Protection Agency, said:"Normal hygiene and cleanliness practices in hospitals should have reduced the likelihood of any significant intake by NHS staff and others and therefore any radiation hazard.

"Nevertheless it is prudent to monitor as a precaution those people who came into direct and close contact with Mr Litvinenko to ensure there has been no cross contamination - Agency staff are meeting with these people urgently.

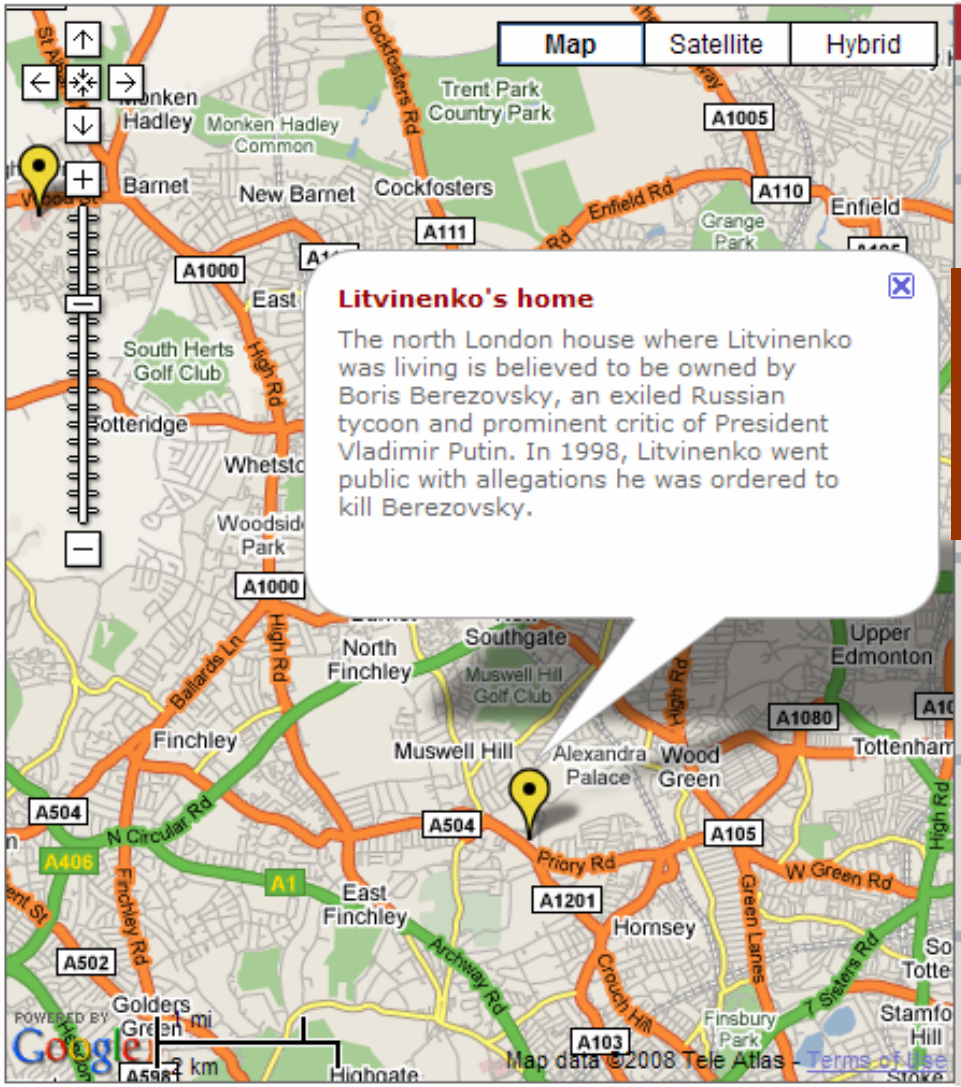
"Other people would not be exposed to radiation simply through being near to Mr Litvinenko. There would be a potential radiological hazard to people who could have ingested or breathed in the contaminated body fluids, but this hazard is likely to be restricted to those who have had very close contact with Mr Litvinenko."

INTERACTIVE MAP

Alexander Litvinenko

London radiation locations

More on famous poisonings »



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Nov. 23
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Traces of a radioactive substance are found on two British Airways planes at **Heathrow Airport.**

Dec. 1
Scaramella and Litvinenko's wife, Marina, both test positive for polonium-

News

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Update Statement on the Public Health Issues related to Polonium-210

Printer friendly page (opens new window)

25 November 2006

The Health Protection Agency is providing expert advice on the public health issues surrounding the death of Mr Alexander Litvinenko. Following the results of further assessments we are updating our advice.

Some small quantities of radioactive material have been found in a small number of areas at the Itsu sushi restaurant at 167 Piccadilly, London , and in some areas of the Millennium Hotel, Grosvenor Square , London , and at Mr Litvinenko's home in Muswell Hill.

We are therefore asking anyone who was in the Itsu restaurant, or who was in The Pine Bar or the restaurant of the Millennium Hotel on 1 November to contact NHS Direct on 0845 4647 where they will be given advice on what to do.

The substance found is Polonium-210. The Chief Medical Officer, Professor Sir Liam Donaldson, is issuing advice to GPs and hospitals on the risks and clinical implications of exposure to Polonium-210.

We want to reassure the public that the risk of having been exposed to this substance remains low. It can only represent a radiation hazard if it is taken into the body - by breathing it in, by taking it into the mouth, or if it gets into a wound. It is **not** a radiological hazard as long as it remains outside the body. Most traces of it can be eliminated through handwashing, or washing machine and dishwasher cycles.

The Agency is also investigating the clinical areas of the two hospitals where Mr Litvinenko was treated.

The police investigation continues. We will provide further public information as appropriate.

If you are an overseas visitor and were in any of the above places on the dates listed you should email the Health Protection Agency for advice: overseasadvice@hpa.org.uk. If you do not have access to email you can contact NHS Direct on 0845 4647 but only via a mobile telephone.

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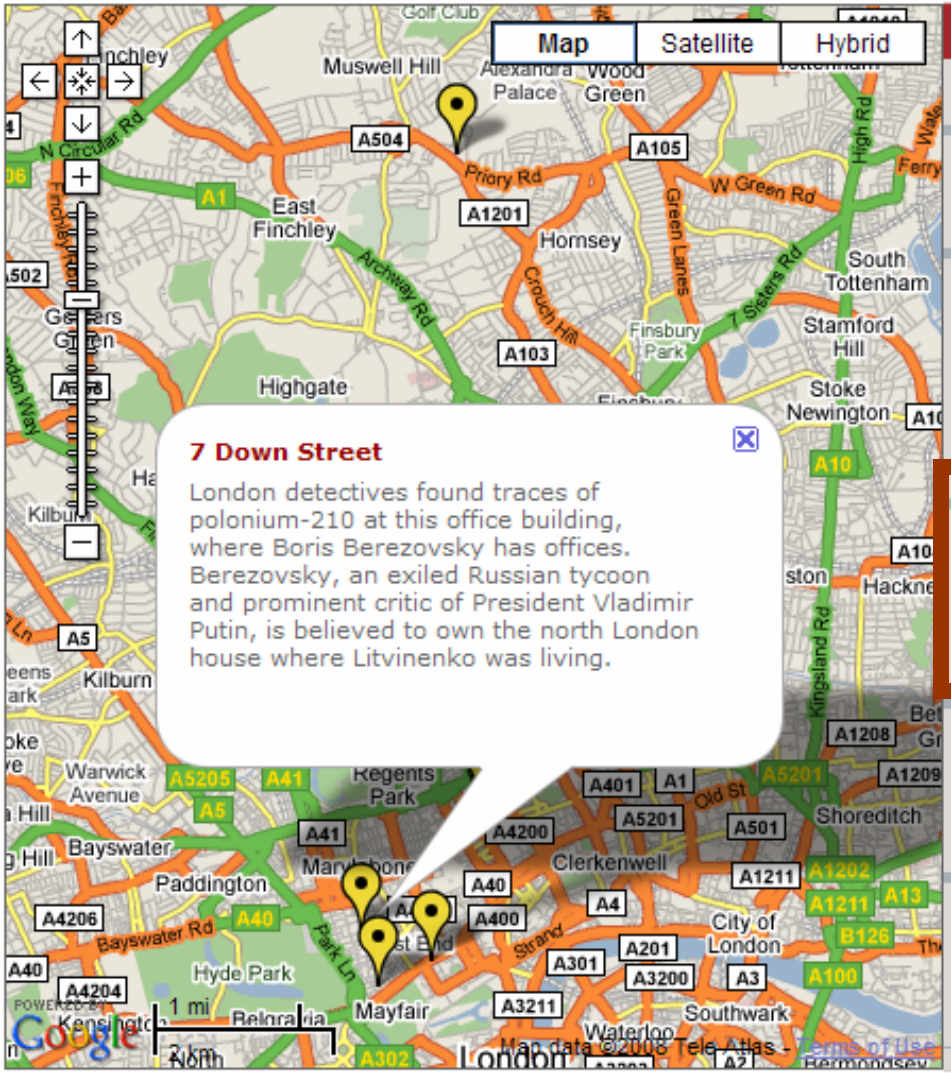

7 Down Street

London detectives found traces of polonium-210 at this office building, where Boris Berezovsky has offices. Berezovsky, an exiled Russian tycoon and prominent critic of President Vladimir Putin, is believed to own the north London house where Litvinenko was living.

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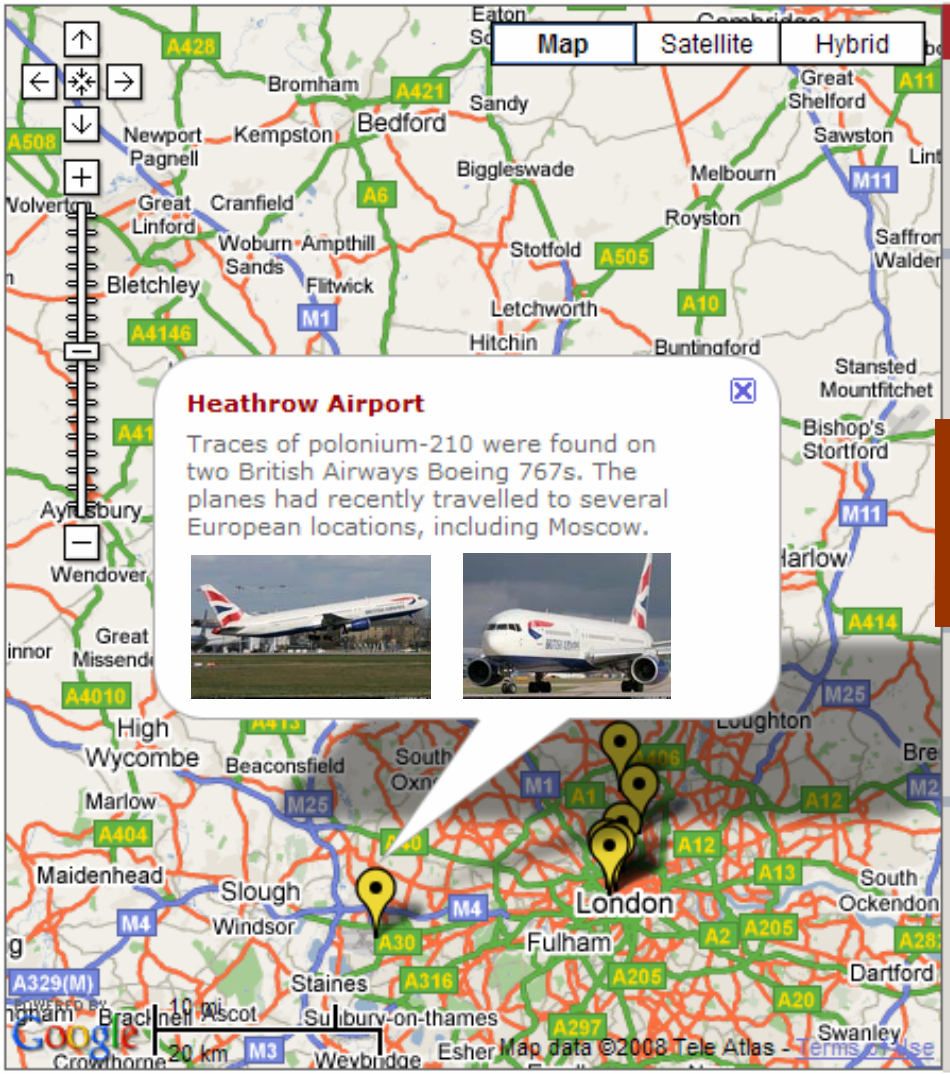

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Dec. 5
Traces of polonium-210 are found at **Emirates Stadium**, where the Arsenal soccer team plays. Ex-KGB agent Vyacheslav Sokolenko attended a game here during his stay at the **Millennium**

British Airways attempted to contact 33,000 passengers who had flown on three jets to or from London's Heathrow Airport between October 25 and November 29, after radiation was found on two of them. British Airways subsequently gave the "all clear" to the jets removed from service. This map shows the planes' destinations.

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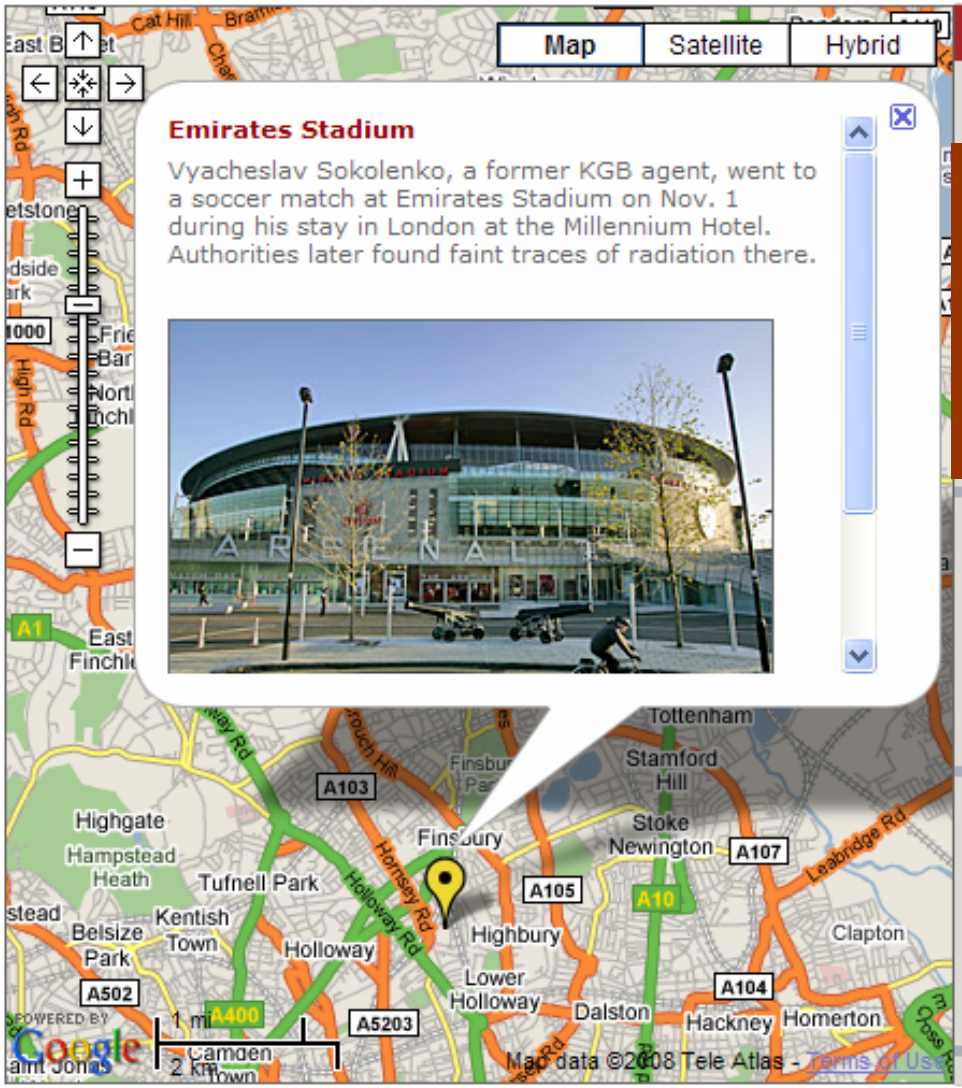

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Dec. 6
British police say they are treating Litvinenko's death as a murder. Radiation is found at the **British embassy in Moscow**. Lugovoi visited the embassy a week after Litvinenko's death.

Dec. 7
Litvinenko is buried at Highgate Cemetery in London. All seven employees working at the Pine Bar in the **Millennium Hotel** on Nov. 1 test positive for low levels of polonium-210.

Dec. 9

The Initiating Event…

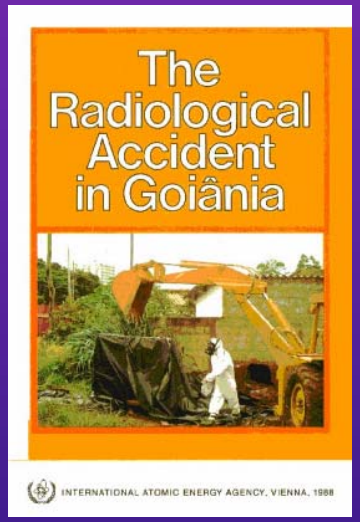
…was a

Radiological Dispersal Event

- One person died
- Tens of thousands potentially contaminated
- Contamination found in public places all around London
  - Hotels (3 primarily)
  - Restaurants & Coffee houses
  - Hospitals
  - Office buildings
  - Taxi cabs, cars, airplanes
  - Soccer stadium
  - Nightclubs & Lap-dance bar

Goiânia, Brazil, 1987

- Cesium-137 dispersal event
- 249 exposed/contaminated
  - 54 hospitalized
  - 46 treated with medication up to 150 days (ages 4 to 38)
  - 8 with radiation sickness
  - 4 deaths
- >110,000 people monitored for contamination



Goiânia, Brazil, 1987

- 85 homes contaminated
- 41 homes evacuated and destroyed
- 3500 cubic meters of contaminated waste (275 truckloads)
- Waste stored at remote site 20 miles away

Radiological Dispersal Event

Response to Po-210

United Kingdom

- New Scotland Yard: criminal investigation
- City of Westminster: recovery & clean-up
- Health Protection Agency (HPA): public health

Public Health Focus for Polonium Incident

Prevent further contamination of the public

- Share information on potentially contaminated sites
- Develop monitoring strategy and co-ordinate assets
- Provide credible advice on public access or remediation

Assess health risks to those contaminated

- Formulate monitoring strategy through urine analysis

Identify and inform those requiring medical follow-up

Provide reassurance to those contaminated and to public at-large

Individual Monitoring Strategy

Direct assessment of contamination feasible through measurement of 210Po in urine (potentially large numbers)

- Initially: staff at two hospitals, sushi bar, friends and family (a few tens)
- Rapidly expanded to hundreds with additional locations

Strategy: obtain samples from those with greatest potential for contamination (i.e., being in a particular location at a particular time). Provides important information on:

- Whether or not the individual who gave sample had an intake of concern for health effects
- Potential contamination of other people in similar situations

Provides reassurance to people with lower potential for contamination (typically at the same place, but later)

Interpreting Po-210 in Urine

- Assess radiation dose associated with Po-210 concentration in 24 hour urine collection sample
- Limits set at:
  - < 1 millisievert (mSv) [100 millirem]
    - No concern for adverse effects
  - ≥ 1 mSv but <6 mSv
    - Contaminated, but no concern for adverse effects
  - ≥ 6 mSv
    - Some concern for increased lifetime risk of fatal cancer

1 mSv increases lifetime fatal cancer risk over baseline: 0.005%

Who was Contaminated?

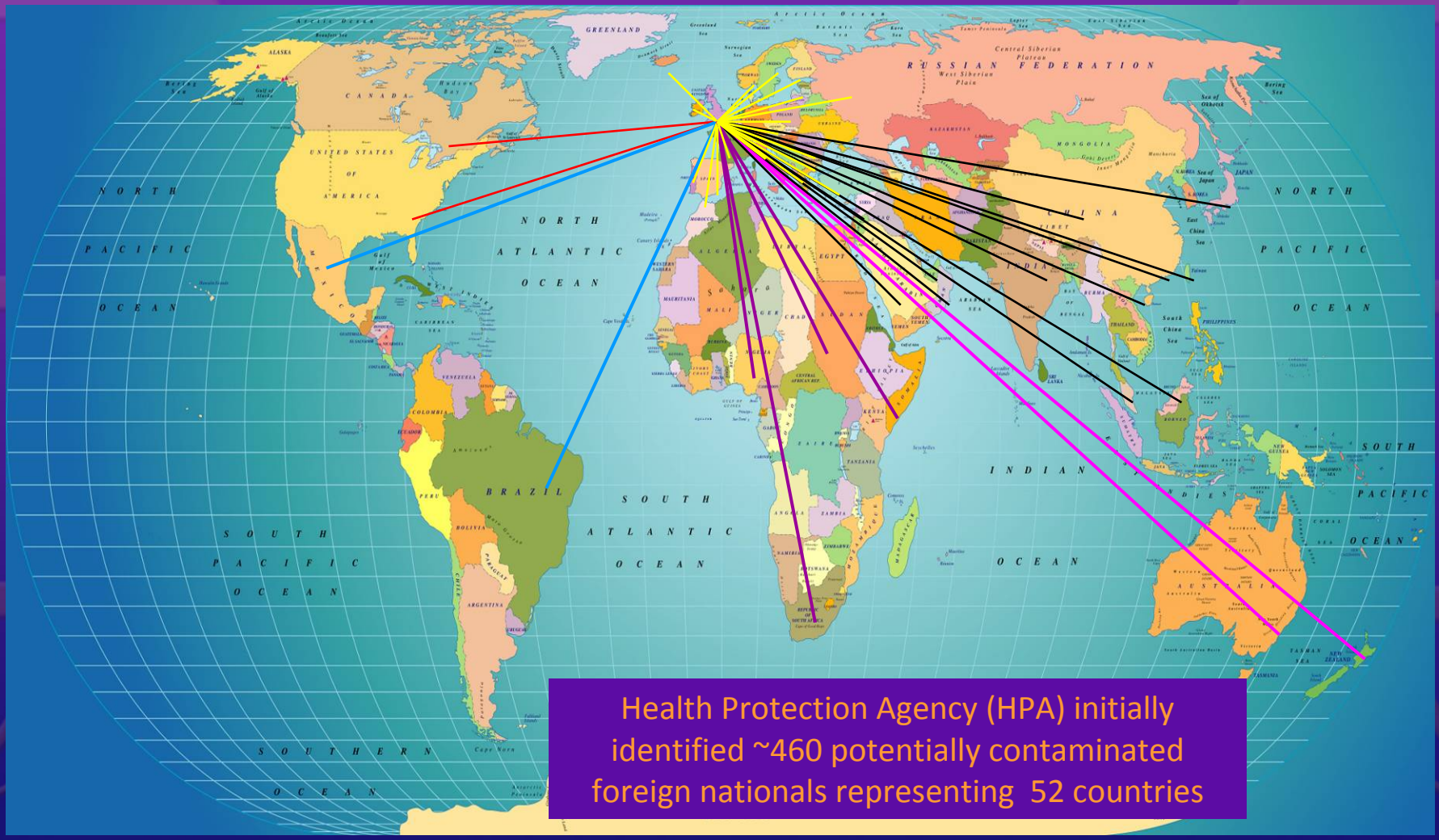
- Hospital staff
  - In contact with radioactive bodily fluids
  - Potential routes of intake
    - Inhalation, ingestion, open wounds
  - PPE and Universal precautions effective
- Hotel and restaurant staff/patrons
- Visitors and tourists from outside UK

U.K. Urine Analyses Results

	Samples Assessed	< 1 mSv	≥ 1mSv and < 6 mSv	≥ 6 mSv
Healthcare	78	77	1	0
Non-Healthcare	660	609	34	17
Totals	738	686	35	17

3/23/2007

International Follow-Up



Potentially Contaminated Visitors

- Foreign nationals identified by credit card receipts and hotel registry information
  - Lists of names collected from hotels, coffee houses, etc., known to be “more heavily” contaminated with Po-210
- Initial HPA list included 140 U.S. citizens (roughly 30% of total)
  - Clearly an underestimate

Response to Po-210

United States

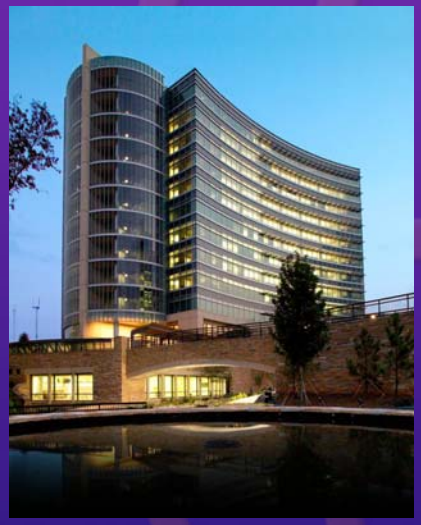
- State and local agencies
- Federal agency support
  - Dept. of Justice / FBI
  - EPA
  - Dept. of Health & Human Services / CDC
    - Main U.S. citizen contact point
  - DOE
  - State Department

24 Nov: Media inquiry to CDC

"What is Polonium-210?"

Basic CDC Public Health Message

- "…*IF* you were at any of the affected locations *AND* you have specific concerns about your health…"
  - See your personal physician
  - Your personal physician can contact your State, local, or tribal health department for further information
  - CDC is available to assist with advice or interpretation of monitoring results



CDC

SAFER·HEALTHIER·PEOPLE™

Key Message Communication

- Informational fact sheets posted on CDC web site
- Messages to public health community issued via Health Alert Network (HAN) & Epi-X
- Attempts made to contact individual U.S. citizens by telephone, e-mail, & U.S. mail
  - Initial list of names (~30) provided by HPA contacted by CDC staff
  - As more names provided, burden of contact passed to State health departments
  - CDC ultimately attempted to contact all U.S. citizens

Known Urine Test Results

- To date, CDC has received urine monitoring results for 31 U.S. citizens (denominator ???)
  - 9/31: originally identified on list provided by HPA
  - 16/31: identified by CDC through contact tracing
  - Additional 6/31: unknown to HPA or CDC
- ALL results below limit of concern for both short- and long-term adverse health effects

Issues Identified #1

- Appropriate international contacts needed
  - HPA reported difficulty contacting appropriate authorities in many of the 52 countries identified
  - International community must work together
  - New agreements with World Health Organization require international notification of radiation events

Issues Identified #2

- Appropriate follow-up of affected citizens
  - U.S. health care system significantly less centralized than U.K. system
  - Initial contact and subsequent follow up of U.S. citizens more difficult
  - CDC found it difficult to respond to certain enquiries from HPA due to lack of information

Issues Identified #3

- Individual privacy concerns
  - U.S. citizens referred to private physicians
  - Po-210 concentration in 24 hour urine samples measured by private laboratories
    - Laboratories unwilling to provide results without client permission
  - CDC can never be sure that it has received results for all Po-210 urine sample measurements

Issues Identified #4

- Laboratory analysis issues
  - 24 hour urine collection needed
  - Days required to conduct analysis
  - Limited public health laboratory capacity
- Division of Laboratory Sciences (CDC) developing new analysis methods using small sample aliquots
- DHHS seeking resources to develop public health Laboratory Response Network for radionuclides

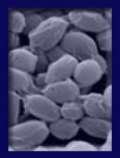
Issues Identified #5

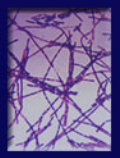
- Public Health Preparedness
  - In U.S., State and local public health agencies unsure of their responsibilities after a radiological/nuclear event
  - Public health officials and radiation experts do not speak the same language
  - CDC is preparing materials for – and is working with national professional organizations to improve communications with – the public health community

Questions?







Radiation Exposure

ACTIVITY / CONDITION	DOSE (in mSv)
LA-NY round trip flight	0.05
Chest x-ray (2 views)	0.08-0.1
Average annual dose of background radiation in US	3.6
Abdominal CT scan	10
Ionizing Radiation Occupational Exposure Limit	50
Smoking 1.5 packs per day for a year	160
Mild acute radiation sickness	2000
Dose to kill 50% of exposed people within 60 days	4500